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High Level Design

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1. Introduction

Conducting and analyzing electroencephalograms (EEGs, henceforth) historically have required a hospital setting with expensive machinery. Due to increases in technology and the “open-source” community’s ingenuity, consumer level EEG devices are now affordable, attainable, and intuitive to use. By working with these devices, we open up a new spectrum of research tools and opportunities, especially in the field of rehabilitation for stroke victims and patients with Attention Deficit Disorder (ADD). These tools will give doctors and lab assistants the ability to monitor concentration and relaxation levels in their patients while they try to conduct a task to better be able to help them in their rehabilitation.

2. Problem Statement and Proposed Solution

Cognitive therapy has always been administered by a specialized doctor to those who have suffered from a stroke or for those who struggle with ADD. This therapy is found to be very useful in a patent's recovery but limited by the amount of time a doctor can allocate to a patient. Patients may only get an hour a week of therapy even they would benefit with more therapy time.

Thus, we are proposing a Cognitive Therapy System(CTS), a system that incorporates a consumer-affordable EEG (electroencephalogram) in the form of a headset no bulkier than standard wrap-around headphones and series of add-ons such as a robotic arm and an led array. The headset will read signals directly from the user without them having to physically manipulate the system, send those signals to a computer to be processed, and pass the correct commands to a microcontroller which will control the robotic arm or LED arrays.

This solution returns functionality to a user, has a relatively low cost, and can be implemented efficiently as the system can be customized to a user and can be mass produced. The headset provides a non-invasive way to monitor a user’s brainwaves and can be removed easily at the end of the day with no discomfort to the user. This will then be used in conjunction with current therapy methods to increase the amount of therapy given to patients and monitor their progress.

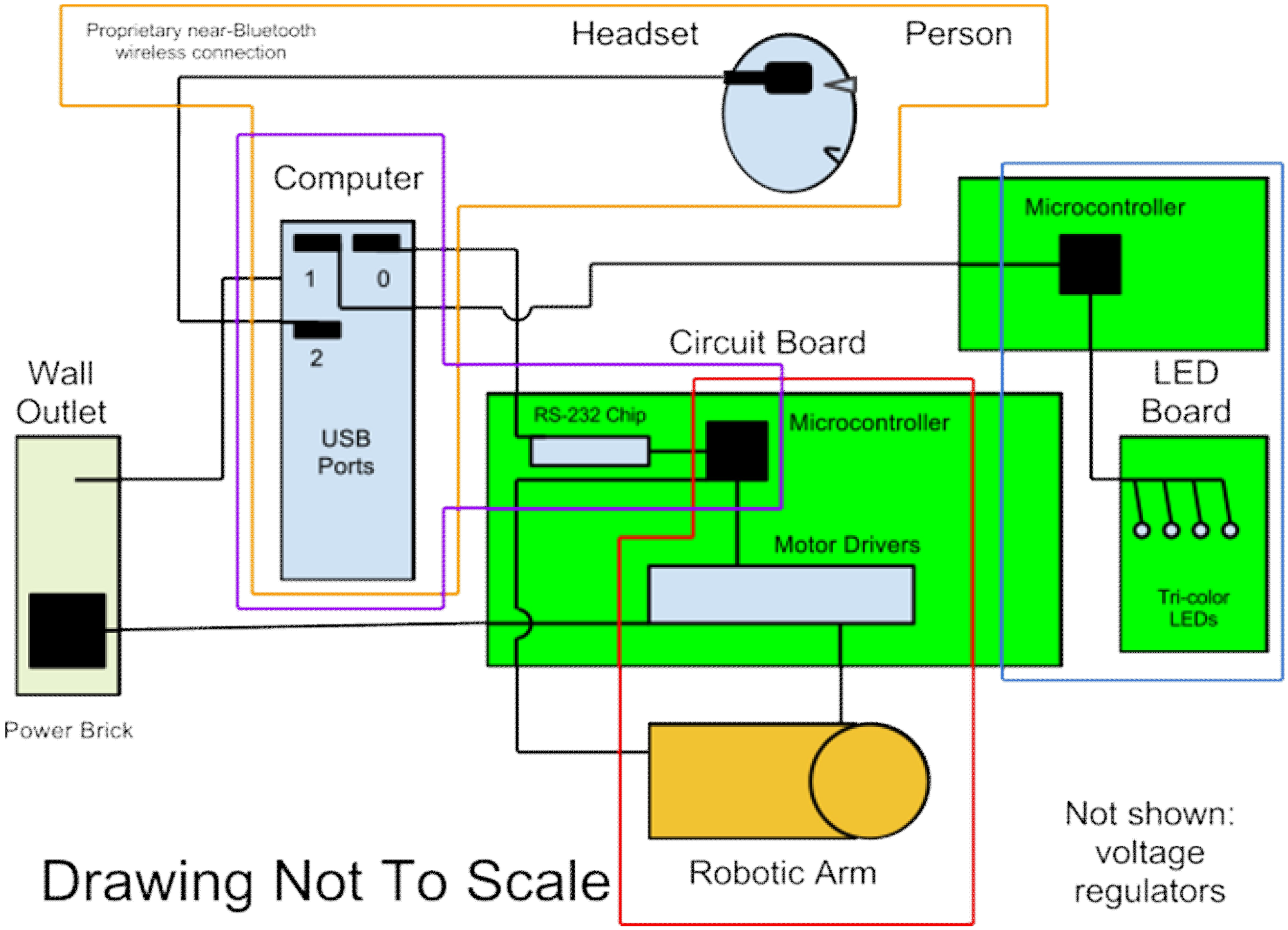
3. System Requirements

Listed below are the requirements this system must meet in order to be effective:

1. The system must be reliable. A patient should not be in the middle of therapy only to have the device fail halfway through. The patient should expect the system to respond to thoughts promptly.
2. The system should be accessible to all patients. This means a relatively short training and calibration period.
3. The system must interest children of a range of ages. Therefore it will use LEDs and a robotic arm as reward mechanisms.
4. System must have non-volatile memory. After shutting down to conserve power, upon restart the system must be able to resume operation in a manner customized to its particular user.
5. The headset must be easy to wear.
6. The headset must be easily removable.

4. **System Block Diagram**

1. *Overall System Components List:* Wall Power, Power Brick, Computer, RS-232 Chip, Microcontroller, Motor Drivers, LED Drivers, Robotic Arm, Headset, Human Head



2. *Subsystem and Interface Requirements:*

Human Head

1. Must be able to concentrate and relax to operate system. There is a minimum threshold of consistency to meet during training. This threshold is also used as a target during operation.

EEG Headset

1. Must reliably, accurately, and continuously take EEG data from user and transmit this to the computer.
2. Must be battery powered.

Computer

1. Software must calibrate itself to the user. For every degree of freedom required in the system, the training program should identify an appropriate thought-pattern that will be used to control that degree of freedom.

2. Must be able to accurately and consistently map thought-patterns to a specific reward.
3. Must be able to control the motors on the robotic arm.
4. Must be able to send appropriate signals to the LED drivers.
5. Must have non-volatile memory.

Robotic Arm

1. Must be relatively lightweight.
2. Must be able to receive motor instructions from the microcontroller
3. Must be able to complete tasks fit for an ADA-approved workplace

LED Drivers

1. Must be able to receive signals from the microcontroller
2. Must be able to control LEDs, including the ability to light up different colors.

3. *Future Enhancement Requirements*

Functionality addition:

Since we have accomplished the acquisition and processing of data, we could move beyond concentration and use other thoughts to trigger certain events on the arm, LEDs, or even other devices added to the system.

Aesthetic modification:

With more resources at our disposal, we could make the arm more visually appealing. Such a change would involve modifying the exterior of our arm to catch the patient's interest in such a way that would make the arm's motion a more satisfying reward. For example, this could include making the arm appear more like a human arm.

5. High Level Design Decisions

The final design will include the following systems: EEG acquisition device, a GUI running on a Linux laptop which will perform the signal analysis, a board which will control the robotic arm and LED array peripherals.

The EEG-monitor we aim to use is called EPOC. We plan to purchase the cheaper version of the headset and use the open source "emokit" software. This headset must yield EEG information that can be analyzed to yield the user's level of concentration. The EPOC headset uses 16 sensors placed in different locations on the users head. The abundance of sensors in different locations will allow us to measure user concentration.

The board will be controlled by the 44 pin PIC18F47J53 (TQFP) microcontroller. It has been chosen for its ability to use I2C, its two USARTs, and its abundance of I/O pins. Power will be supplied from the USB connection to the Linux computer. The USB power is fed into a voltage regulator to run the board at 3.2 volts.

The LED array will be used to display the concentration levels achieved by the user. In order for the feedback of the LED's to be more impressive and effective (with respect to patients with ADD/ADHD) the project requires many fairly bright LED's. It consists of

16 multi-colored LED's controlled by two NXP I2C LED drivers (PCA 9626) . In order to conserve I/O pins and to allow the LED colors to be altered in software an LED driver is required. Altering the LED colors in software will increase the systems' adaptability to different patients (who may have different favorite colors). Since our LED array contains 48 LED's (16 RGB multicolored LEDs) it was also necessary to choose LED drivers with an abundance of driving pins. The power to for the drivers comes from a wall wart and not the USB source powering the board.

The OWI Robotic Arm Edge Robotics Kit is an inexpensive robotic arm with 3 degrees of motion. Since we do not require many degrees of motion, and we do not require state-feedback the OWI Robotic Arm is a suitable choice. The arm's motors are controlled by two motor drivers: _______ . The power for the arm is also drawn from the wall wart that supplies the LED's. We plan to only use one of these two peripherals at any given time so as to have enough current supply.

Because of the complexity and limitations of brain wave signals, there will have to be a training program that each user will have to go through. The training software will have the user practice producing different mind states and setting those states to control commands. The training will range from about a half an hour to an hour.

6. Open Questions

1. **How do we design the board?**
Board Design is an open question that cannot be resolved until the group is more aware of the electronic limitations capabilities of the other components to the project, namely the OWI arm, OWI software/interfacing method, notification devices et cetera. Good board design will be a critical component of our project. Also we are open to adding new features and these will certainly affect the final design of our board so.

2. **What microcontroller do we use?**
Choosing a microcontroller is a design question similar to designing a board in that it requires a better knowledge of the other project components. Attributes that need to be considered in relation to the other components include: memory, speed, price, and compatibility with various interfaces. Though not likely, the size of our microcontroller could be an issue and design objective if we end up having limited space.

3. **How do we interface everything?**
Each of the project components must interface with at least one other component.
The components do not use the same modes of communication. Making sure that the data is compatible with the microprocessor and reaches the board in a timely manner is a necessity. Before this question can be addressed the OWI arm, mind-control headset and LED drivers must be chosen and examined. Answering this question would also affect our choice on microcontroller and ultimately, our final board design.

4. **Can we get state feedback from the arm?**

This solution to this question depends upon the choice of arm and the software package that accompanies it. State feedback is the simplest way to guarantee stability of the system, thus it is crucial to be able to access the state data in a timely manner from the arm.

5. **What type of reward system do we want?**
This is one of our bigger questions because it essentially affects the whole design and component choices. Since our project is for aiding primarily stroke victims and possibly ADHD patients, we will need to come up with an adequate rewards system for them to give back feed back for the progress being made. We have to make the decision of the desired level of complexity of our LED display. Do we want a particular color to correspond to each calibrated concentration level or do we want to spell things out and make patterns instead? This would also influence our decision of weather or not we want multicolor LEDs as opposed to monochromatic. For the arm, do we want to program a previously defined motion routine that would correspond to an achieved concentration level? Do we instead want do have one task that requires various concentration levels to complete it? All these questions are to be addressed.

6**. How can we train people?**
The choice of mind-control headset and the software that accompanies it will help us to determine this question. Creating a reliable method for training people to use the mind control headset to control the OWI arm will probably not be a trivial task, especially considering our desire to obtain as many degrees of freedom as possible. Thus the user must be able to generate a few distinct types of signals that can be interpreted to control the arm and LEDs. We essentially need to also work on the reproducibility and reliability of our system, making sure that, at all times we are measuring concentration and mapping only its level to the visible actions of the arm and LEDs.

7. Major Component Costs

EPOC EEG: $300
This covers the cost for a high resolution, neuro-signal acquisition and processing wireless neuroheadset fully equipped with sensors to harness the electric signals produced by our brain. Apart from being an essentials part of our project, this technology is dynamic enough to be used by other groups in the future.

Microcontroller and board: $15
We envision that we will need a 64-pin microcontroller. These typically range from $3 to $6 based on the specifications and particular characteristics and capabilities.

OWI Robotic arm with USB interface: $70.00
The OWI arm with a USB interface is listed at $69.95 from the vendor. The USB would ensure streamline interface from one component of our system to the other and would afford us the luxury of connecting the arm directly to a computer for routine tasks like running tests programs and troubleshooting.

Other costs: $20.00
We will need to purchase two LED driver and multiple sets of LEDS. We chose multicolor LEDs because that gives us the greatest degree of freedom for our design.

6. Conclusions

Utilizing consumer-EEG devices in such a way is a novel technique with a lot of potential to help the intended audience. While this would be no substitute for professional-grade EEG for diagnosis, the MINDARMTHING package is an incredibly affordable system with which to use in a rehabilitation setting. Using this tool will hopefully allow patients to progress much more rapidly than they could previously while also providing lab personnel with a detailed view into the inner workings of the patient's mind.

9 References

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